DEPENDENCE OF MULTIPLEXED HOLOGRAM RECORDING CHARACTERISTICS ON MONOMER DIFFUSION AND REACTION PARAMETERS OF PHOTOPOLYMER MEDIA

Akiyo GOTO[1], Shuhei YOSHIDA[1], Naruki YOSHIDA[1], Manabu YAMAMOTO[1], Tomoya MIZUTA[2], Hiroto MIYAKE[2], Kyohei FUKAYA[3], Ken'ichi KOSEKI[3]

[1]Industrial Science and Technology, Tokyo University of Science

[2]Daicel Chemical Industries, Ltd.

[3]Advanced Integration Science, Chiba University

Introduction

Many studies have been conducted on photopolymers as promising holographic recording media. Aiming to develop high-speed large-volume memory media, many researchers have reported on the choice of materials. An important factor limiting practical applications is that the dependence of recording characteristics on many media parameters is not clarified. This paper compares a numerical simulation developed by the authors for analyzing the recording and reproduction processes of photopolymers, with the results of recording experiments. Furthermore, we analyze multiplex recording characteristics, which depend on media parameters such as the diffusion constant D and the rate constants of termination k_t and polymerization k_p. In particular, to speed up the recording process, the dependence on media parameters is investigated.

Photopolymer's reaction-diffusion process and the numerical analysis method

In the recording process, first, an intensity distribution is generated in the media by the interference between reference light and signal light. Second, monomers polymerize in the bright section, and diffuse and enhance polymerization. As a result, a refractive index distribution is formed in accordance with the light intensity distribution. This is the simplified mechanism of recording a hologram. Our numerical analysis assumes that the reaction -diffusion process consists of four steps:

(1) Initiation: The initiator is decomposed into polymerization initiation radicals by recording light. Monomers react with the radicals and are radicalized.

(2) Propagation: The radicalized monomers react with monomers in turn and more polymers are produced.

(3) Termination: Radicals of the produced polymers are inactivated and the polymerization reaction comes to a halt.

(4) Chain transfer: A chain reaction newly begins when the polymers have grown to a certain molecular weight.

On the other hand, the diffracted light distribution, which results from the refractive index change, is calculated by the FD-BPM method. The reproduction light, which is approximated by a plane wave, is incident on the media down to a depth of several hundred μm. The time dependent reaction-diffusion processes are simulated to calculate the change in the intensity of diffracted light.

Experimental setup and holographic recording material

In the experimental system for evaluating basic characteristics, holographic recording is conducted using a two-beam interference method shown in Figure 1. A green laser with a wavelength of 532 nm is used for recording, and green (532 nm) or red (633 nm) wavelength for reproduction. A red light is used for reproduction to prevent recording during the reproduction process. The interference patterns are also measured in real time during recording. A holographic recording material, consisting of cationic curing compounds, binder polymer, photo-acid-generator, sensitive dye, and solvent, was coated on glass plate to become 100μm in film thickness, and then 200μm of polycarbonate film was covered. This was prepared holographic recording media.

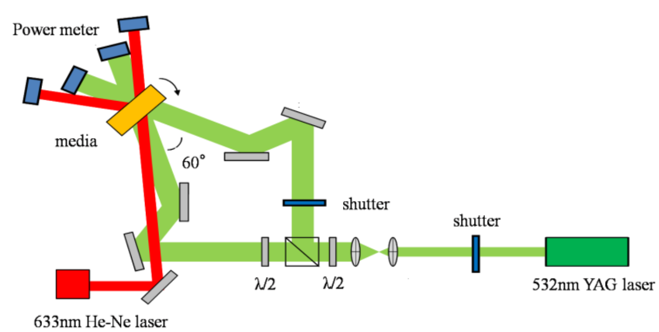

Fig. 1 Experimental setup of a two-beam interference method

Extraction of media parameters by data fitting

In this study, the rate constants of polymerization k_p and termination k_t and the diffusion rate D, are extracted from the data fitting from the experimental relation between recording time and diffraction efficiency. The recording-reproducing process simulator of Yoshida et al. [1] is used. From the data fitting, the extracted rate constants of polymerization k_p and termination k_t are 0.001 (1/s) and 1 (1/s), respectively, and the diffusion rate D is 6×10^{-16} (m^2/Ws).

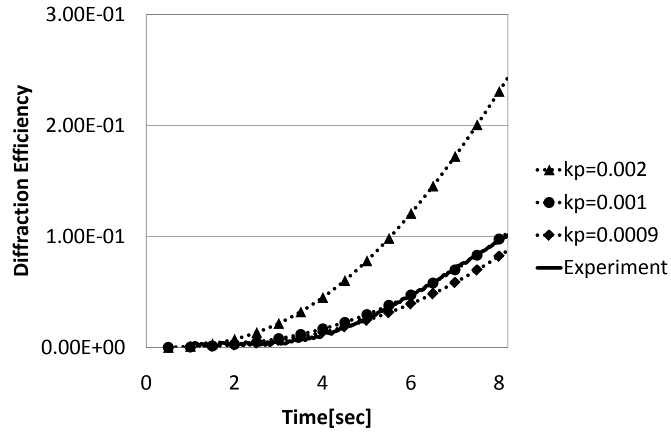

Fig. 2 Relationship between recording time and diffraction efficiency

Fig. 2 shows the experimental relation between recording time and diffraction efficiency. The broken curve in Fig. 2 shows the result of numerical analysis using the constants obtained by fitting in the approximately linear portion of the curve in Fig. 2. Incident laser power is 10 mW, and the diffraction efficiency is for the reproduction wavelength of 532 nm. The media film thickness is 100 µm.

Evaluation of scheduling characteristics in multiplexed recording

Ten multiplexed recording was performed using the media discussed in terms of fitting in former section. Fig. 3 compares the experimental result after scheduling and the result of simulation assuming the same recording conditions.

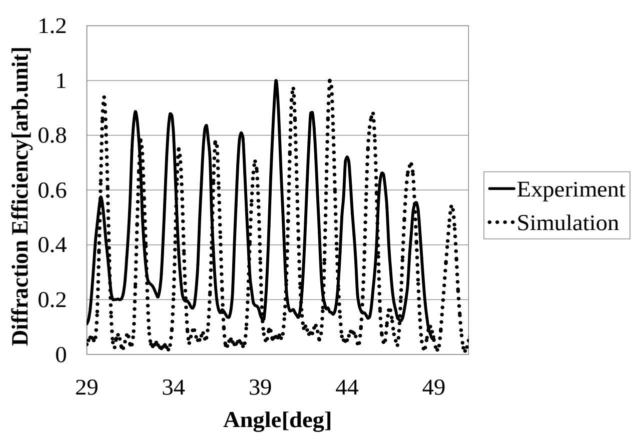

Fig. 3 Experimental and simulation result of scheduling

The simulation uses the rate constants of polymerization k_p and termination k_t, and the diffusion coefficient D extracted from fitting. The simulation result agrees well with the experimental result.

The relation between media parameters, as explained in the previous section and high-speed multiplex recording characteristics is examined. Table 1 shows the media parameters for high-speed recording. Fig. 4 shows the simulation of high-speed recording using different values and rate constants of termination.

Table 1 Media parameters for high-speed recording

	Sample A	Sample B	Sample C
Termination rate : kt [1/s]	1000	10	1
Polymerization rate : kp [1/s]	0.001	0.001	0.001

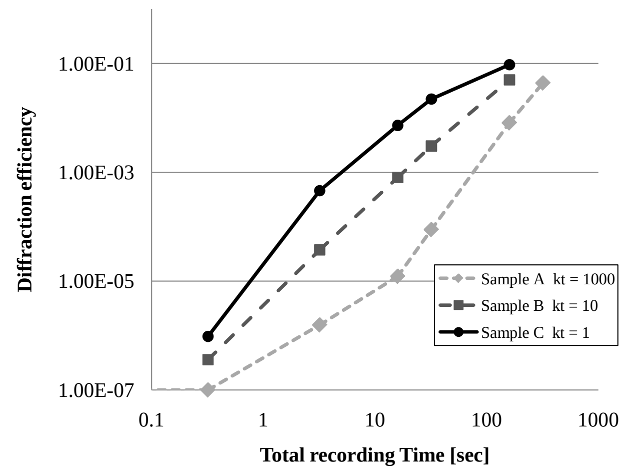

Fig.4 High-speed recording using different values of and rate constants of termination

The figure shows the relation between the total sum of exposure time and recording time interval for 10 multiplex recording. Fig. 4 clearly shows that the high-speed recording characteristics with the media parameters are greatly improved. It is clear that the rate constant of termination k_t greatly affect the high-speed recording characteristics.

Conclusions

In this study, using the media parameters extracted from the data fitting from the experimental relation between recording time and diffraction efficiency, multiplex recording characteristics were simulated. A good agreement with the experiment was confirmed. Furthermore, the simulation suggested that media parameters such as the rate constants of termination and polymerization, greatly affect the recording speed.

Reference

1 S. Yoshida and M. Yamamoto, "Analysis of Diffraction Characteristics of Holographic Grating in Photopolymer Films by Beam Propagation Method," *Jpn. J. Appl. Phys.*, **48** (2009), 03A027.